HIPSTARS 2024 - Workshop on Heavy Ion Physics and Compact Stars

Monday 21 October 2024 - Friday 25 October 2024

Havana

Book of Abstracts

The event is a virtual spin-off of the series of meetings STARS/SMFNS gathering scientists from all over the world, with the purpose of establishing connections between the different communities within the scope of the conference and encouraging the participation of students and young researchers. The meeting sessions will consist of contributed talks covering recent developments in the following topics: Heavy ion collisions and the formation of the quark-gluon plasma, relativistic and nuclear astrophysics, compact stars, gravitation and related topics.

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How to find variable sources in low count rate X-ray all-sky surveys

Author: Thomas Boller[None]

We provide the first analysis of the variable X-ray sky obtained with eROSITA using standard normalized excess variance, maximum amplitude variability tests, and Bayesian tests to constrain the variability of different object classes.

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Space-time emergence and machine learning

Author: Nana Geraldine Cabo Bizet[None]

The work explores the emergence of space-time from tensor networks. Following a known prescription we construct a bulk 2D Ising model, whose free energy captures the partition function of a random tensor network, reproducing the entanglement entropy of particular boundary theories. We assume the Ryu-Takayanagi formula, and the Ising model couplings are obtained with a machine learning optimization algorithm. We explore the networks associated to the geometries of AdS_3 and the one of the Bañados, Teitelboim, and Zanelli (BTZ) Black Hole.

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Resonance suppression during the hadronic stage from the FAIR to the intermediate RHIC energy regime

Author: Amine Chabane[None]

The energy and centrality dependence of the kaon resonance ratio $(K^{*0} + \bar{K}^{*0})/(K^+ + K^-)$ is explored in the RHIC-BES and CBM-FAIR energy regime. To this aim, the Ultra-relativistic Quantum Molecular Dynamics (UrQMD) model is employed to simulate reconstructable K^* resonances in Au+Au and p+p collisions from $\sqrt{s_{\rm NN}} = 3 - 39$ GeV. We obtain a good description of the resonance yields and mean transverse momenta over the whole investigated energy range. The decrease of the K^*/K ratio, with increasing centrality is in line with the available experimental data. We also observe the experimenatlly measured increase in $\langle p_{\rm T} \rangle$ with increasing centrality which is interpreted as a lower reconstruction probability of low-$p_{\rm T}$ K^* due to the $p_{\rm T}$ dependent absorption of the decay daughter hadrons. We conclude that the observed suppression of reconstructable K^* resonances provides a strong sign of an extended hadronic rescattering stage at all investigated energies. Its duration increases from peripheral to central reactions as expected. Following a method, suggested by the STAR experiment, the "duration" of the hadronic stage is extracted using the K^*/K ratios at chemical and kinetic freeze-out. The resulting lifetimes are in good agreement with the experimental data, but much shorter than the actual lifetime of the hadronic phase in the transport simulation. This indicates that the experimental method to estimate the life time of the hadronic stage is too simplified.

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Jets induced by chiral currents in the magnetosphere of a rotating black hole.

Author: Eduardo García Reynaldo[None]

We study the possible generation of relativistic jets induced by a chiral imbalance in a strongly magnetized electron–positron plasma in magnetospheres of spinning black holes. Stationary, axisymmetric, force–free magnetospheres Kerr black holes are analyzed. We explore the chiral symmetry breaking induced by longitudinal photons as a possible condition for the creation of relativistic jets. We report an electric current, and discuss its structure in terms of the scattering and creation of electron-positron pairs resulting from the decay of the longitudinal photons in a magnetized medium. The present results are based on the quantum field theory formalism at finite temperature and density.

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Neutrino oscillations and spontaneous breaking of the Lorentz symmetry.

Author: Israel Hernández Sehara[None]

Nowadays the neutrino oscillations is one of the main problems in particle physics. The problem of the mass, which is an essential condition to describe the oscillation of flavors is not clear. Experimental evidence suggests the possibility of a new physics beyond standard model where the neutrino oscillations can be understood. On the other hand, the spontaneous breaking of Lorentz symmetry, originally introduced in string theories, provides the possibility of establish a connection between the flavor dynamics and the time space structure. In this work, Lorentz-violating tensor is introduced in the Dirac lagrangian. We study the structure of a non dynamical tensor and calculate the fermionic propagator associated to flavor oscillations. We study the relation between the space-time structure and the flavor dynamics by using the dispersion relation calculated. These results are applied to the neutrino oscillations model.

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Negative magnetoresistance induced by longitudinal photons in Dirac/Weyl semimetals

Author: Susana Montesino[None]

A low-energy model is built to study systems such as Dirac/Weyl semimetals, according to statistical quantum electrodynamics formalism. We report that the introduction of a pseudoscalar, associated to longitudinal photons propagating along a magnetic field B, could transforms a Dirac semimetal into a Weyl semimetal with a pair of Weyl nodes for each point of Dirac. The nodes are separated by a pseudovector electric field induced dynamically along B associated to a chiral effect on the Fermi surface. A topological quantum transition is produced between a chiral-and non-chiral symmetry phase. A general expression to the longitudinal magnetoconductivity is found. It provides the possibility of generalizing the usual expressions of the magnetoconductivity reported in the literature. This has a quadratic dependence on B, which is associated with a positive contribution to the magnetoconductivity. This is a prominent signature of the chiral magnetic effect in Dirac/Weyl systems in parallel electric and magnetic fields. We report a chiral effect induced by longitudinal photons associated to a negative longitudinal magnetoresistance in Dirac systems via an axial anomaly relation. We show some numerical results, and reproduced with a high level of accuracy some of the experimental results, in the low temperature region, obtained to the magnetoresistance of ZrTe5 and Na3Bi. We believe that a wide variety of these semimetals can be studied by using our general expression to the negative longitudinal magnetoresistance.

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Axial anomaly and breaking of chiral symmetry

Author: Alejandro Orue León[None]

We study the structure of the QCD vacuum, and its relation with the special gluonic configurations. These non-trivial topological configurations so called instantons. The spontaneous chiral symmetry breaking via QCD axial anomlay will be discuss. We propose an effective model starting of the Maxwell-Chern-Simons theory, where a chiral current generation will be calculated associated to an effective mass term induced by a chiral imbalance. We will address the relationship between the mass generation mechanism and the spontaneous breaking of chiral symmetry.

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Flow correlations as precision tool to measure the Equation-of-State

Author: Tom Reichert[None]

Correlations between the harmonic flow coefficients v1, v2, v3 and v4 of nucleons in peripheral Au+Au collisions at 1.23A GeV are investigated with the Ultra-relativistic Quantum Molecular Dynamics model employing different Equations-of-State (hard Skyrme, soft Skyrme, Chiral-Mean-Field). Using an event-by-event selection based on the final state it is shown that the triangular flow changes its slope around midrapidity while the quadrangular flow changes its curvature in these different -event classes. The correlations of the flow coefficients are explained with the intricate time dependence of heavy-ion collisions at low collision energies. The results on the flow correlations thus reveal a strong sensitivity to the EoS which will allow to measure the Equation-of-State at large baryon densities more precisely than is usually possible. Finally the model is used to calculate the first and predict the second order flow coefficients of hypernuclei.

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Photon magnetic properties and radiation pressures in nonlinear electrodynamics

Authors: Adrian William Romero Jorge[1]; Aurora Perez Martinez[None]; Annabel Martinez Gil[2]; Elizabeth Rodriguez[None]

[1] *Frankfurt Institute for Advanced Studies/Goethe University Frankfurt*

[2] *ICIMAF*

Starting from the quadratic expansion in the photon fields of non-linear electrodynamics Lagrangian model, we study relevant vacuum properties in a scenario involving the propagation of a photon probe in the presence of a background constant magnetic field.

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How to find variable sources in low count rate X-ray all-sky surveys

Author: Thomas Boller[None]

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Cluster and hypernuclei production in heavy-ion collisions

Author: Elena Bratkovskaya[None]

We investigate the influence of the equation-of-state (EoS) of strongly interacting hadronic and partonic matter created in heavy-ion collisions on the light cluster and hypernuclei production within the Parton-Hadron-Quantum-Molecular Dynamics (PHQMD) microscopic transport approach (PHQMD) [1-5]. The PHQMD is a microscopic n-body transport model based on the QMD propagation of the baryonic degrees of freedom, where the clusters are formed dynamically, via {\bf 'potential' mechanism}, i.e. by potential interactions between nucleons and hyperons, and recognized by by the Minimum Spanning Tree (MST) algorithm which is identifying bound clusters by correlations of baryons in coordinate space.

Additionally, {\bf 'kinetic' mechanisms for deuteron production} is incorporated by catalytic hadronic reactions accounting all isospin channels of the various $\pi NN \leftrightarrow \pi d$, $NNN \leftrightarrow Nd$ reactions which enhances deuteron production as well as considering the quantum nature of the deuteron by mean of its finite size modelled by the finite-size excluded volume effect in coordinate space and projection of relative momentum of the interacting pair of nucleons on the deuteron wave-function in momentum space, leads to a strong reduction of d production, especially at target/projectile rapidities [4].

Whereas in the previous PHQMD calculations we employed a static interaction between nucleons, now we include a {\bf momentum dependence interaction}. The parameters of the momentum dependent potential are fitted to the 'optical' potential, extracted from elastic pA scattering data. The potential is increasingly repulsive up to $E_{kin} \sim 1.5$ GeV, therefore its influence depends on the beam energy. A momentum dependent interaction acts very differently on flow observables like v_1 or v_2 and cluster rapdity distributions and brings the calculations even closer to the experimental data as a comparison with STAR data shows.

We have furthermore implemented {\bf the coalescence approach in the PHQMD } what allows to compare directly and for the same underlying dynamics the cluster yields, created by MST+kinetic mechanisms and coalescence mechanism. We could establish that both methods yield different cluster rapidity distributions. This allows to {\bf determine the cluster production mechanism experimentally}. Finally we will present a solution of the 'ice in the fire' puzzle, the question how cluster can survive the expansion of the hot and strongly interacting fireball at midrapidity.

[1] J. Aichelin, E. Bratkovskaya, A. Le Faevre, V. Kireyeu, V. Kolesnikov, Y. Leifels, V. Voronyuk and G. Coci, Phys. Rev. C 101 (2020) no.4, 044905.
[2] S. Glaessel, V. Kireyeu, V. Voronyuk, J. Aichelin, C. Blume, E. Bratkovskaya, G. Coci, V. Kolesnikov and M. Winn, Phys.Rev. C 105 (2022) no.1, 014908.
[3] V. Kireyeu, J. Steinheimer, J. Aichelin, M. Bleicher and E. Bratkovskaya, Phys. Rev. C 105 (2022) no.4, 044909.
[4] G. Coci, S. Glael, V. Kireyeu, J. Aichelin, C. Blume, E. Bratkovskaya, V. Kolesnikov and V. Voronyuk, Phys. Rev. C 108 (2023) no.1, 014902.
[5] V. Kireyeu, G. Coci, S. Glaessel, J. Aichelin, C. Blume and E. Bratkovskaya, Phys.Rev.C 109 (2024) 4, 044906.

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Magnetized Strange Stars and Gravitational Waves signals

Authors: Aurora Perez Martinez[None]; Daryel Manreza[1]; Gabriel Gil Pérez[2]; Samantha López[None]

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We investigate the emission of gravitational waves from spheroidal, magnetized strange stars in two scenarios: an isolated, slowly rotating star and a binary system. For the isolated star, we compute the

quadrupole moment and the amplitude of the gravitational waves that may be emitted. In the case of the binary system, we determine the tidal deformability by simultaneously solving the spheroidal structure equations and the Love number equation. Our results are compared with data inferred from the GW170817 event, which is also used to estimate the mass and tidal deformability of the companion star in the binary system. Our model supports the existence of binary systems formed by magnetized strange stars, predicting gravitational wave signals that are consistent with other models of binary systems composed of magnetized hadronic stars or non-magnetized quark stars.

8

heavy quark mass in QGP

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Co-authors: Elena Bratkovskaya [1]; Ilia Grishmanovskii [2]; Olga Soloveva [3]; qi zhou

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We investigate heavy quark mass near the phase transition by combining the statistical model on hadronic side and the quasi-particle model on partonic side. We find heavy quark mass much larger than the bare mass in QCD Lagrangian. This massive heavy quark is supported by the thermal production of heavy quark in heavy-ion collision experiments.

7

Transport properties of the strongly interacting quark-gluon plasma

Authors: Ilia Grishmanovskii[1]; Taesoo Song[None]; Olga Soloveva[2]; Elena Bratkovskaya[3]; Carsten Greiner[4]

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We investigate the role of elastic and inelastic processes in the strongly interacting quark-gluon plasma within the effective dynamical quasi-particle model (DQPM) constructed for the description of non-perturbative QCD phenomena of the strongly interacting quark-gluon plasma in line with the lattice QCD equation-of-state.

We present the results for the:
1) Energy, temperature and chemical potential dependencies of the total and differential radiative cross sections and compare them to the corresponding elastic cross sections.
2) Transition rate and relaxation time of radiative versus elastic scatterings.
3) Jet transport coefficients such as the transverse momentum transfer squared per unit length as well as the energy loss per unit length and investigate their dependence on the temperature and momentum of the jet parton depending on the choice of the strong coupling in thermal, jet parton and radiative vertices.

6

Exploring Dark Photon Production and Kinetic Mixing Constraints in Heavy-Ion Collisions

Author: Adrian William Romero Jorge[1]

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The vector U-bosons, or so-called 'dark photons', are potential candidates for dark matter mediators. They are expected to interact with standard matter via a 'vector portal' due to the $U(1) - U(1)'$ symmetry group mixing, which may make them detectable in particle and heavy-ion experiments. Although there has been no confirmed observation of dark photons, detailed analyses of various experimental data have provided upper limits for the kinetic mixing parameter ϵ^2, depending on the mass M_U of U-bosons, which is also currently unknown. In this study, we present a procedure to define theoretical constraints on the upper limit of $\epsilon^2(M_U)$ from heavy-ion as well as $p+p$ and $A+A$ dilepton data from SIS to LHC energies, where dark photons have not been observed. Our analysis is grounded in the microscopic Parton-Hadron-String Dynamics (PHSD) transport approach, which accurately reproduces the measured dilepton spectra in $p + p$, $p + A$, and $A + A$ collisions. In addition to considering the various dilepton channels originating from interactions and decays of ordinary matter particles (mesons and baryons), we incorporate the decay of hypothetical U-bosons to dileptons, $U \rightarrow e^+e^-$. The U-bosons themselves are produced by the Dalitz decay of pions ($\pi^0 \rightarrow \gamma U$), η-mesons ($\eta \rightarrow \gamma U$), and Delta resonances ($\Delta \rightarrow NU$). We also include the Dalitz decay of the ω, direct decays of vector mesons such as the ρ, ω, and ϕ, as well as decays from K^+ mesons. Our analysis can provide insight into the required accuracy for future experimental searches for 'light' dark photons in dilepton experiments.

2

On magnetized Bose-Einstein charged scalar condensate stars

Author: Amanda Castillo Ayón[1]

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We study the thermodynamic properties of a relativistic magnetized scalar charged boson gas at any temperature in the presence of an external magnetic field. We reproduce the low temperature behavior of the boson gas characterized by two plateus of specific heat the first one at 1/2, the reduction on one dimensional gas due to the strong magnetic field provokes that all the bosons are in the lowest Landau level (LLL) and the second at 3/2 when the temperature is higher than the magnetic field and the system recover a 3D behavior.We have obtained the EoS of the gas and we analyze the effect of temperature and magnetic field and the role of antiparticles in the behaviour of thermodynamic magnitudes. Astrophysical implications are discussed.

3

STUDY OF HYPERCOMPACT HII REGIONS BY ASTRONOMICAL OBSERVATIONS

Author: Isabel Tatiana Rodríguez Esnard[1]

[1] *ICIMAF*

Hypercompact HII regions (HC) are regions of ionized gas associated with the earliest stages of high-mass star formation. With the aim of better understanding their characteristics, we have carried out

a study of five candidates for HC HII regions. For this, we performed observations with the Jansky Very Large Array (JVLA) at 2 and 6 cm, with an angular resolution of ~0.900 . As a result, we report the images of the detected sources and the measured parameters. In addition, we explore several possible scenarios, considering both HC HII regions and spherical and collimated winds. Likewise, we have modeled the spectra of these sources as uniform spheres. In general, the sources were unresolved, but by applying the models, we have been able to estimate that their sizes vary in a range of 0.3 to 3.67 mpc, suggesting that they remain candidates for HC HII regions, highlighting G40.28−0.22 as the best representative. We cannot rule out the possibility that some sources are jets or stellar winds.

4

New observational constraints on Bose-Einstein condansate stars

Authors: Adriel Rodriguez[None]; Gretel Quintero Angulo[None]

We evaluate the feasibility of Bose-Einstein condensate stars (BECS) as models for the interior of neutron stars (NSs). BECS are compact objects composed of bosons, formed through the spin-parallel pairing of neutrons. Here, we utilize the astronomical data from GW170817, XMMU J173203.3-344518 (the lightest NS known), and a novel lower limit on NS core heat capacity to scrutinize the compatibility of BECS with these recent observations of NSs. Our specific focus is to constrain the values of the scattering length a, parameter determining the strength of particle interactions in the model. Our analysis suggests that if the stars involved in GW170817 were BECSs, the scattering length of their constituent bosons should fall within the 4 to 10 fm range. Additionally, at a scattering length of a~3.1−4 fm, stars with mass and radius characteristics akin to XMMU J173203.3-344518 are identified. Moreover, we find that the heat capacity depends on the mass and temperature of BECS, and surpasses the established lower bound for NS cores when a>2−5 fm. In summary, our results endorse BECS models with a~4 fm, providing NS observables in agreement with diverse observations and contributing to the understanding of NS interiors.

5

Deuteron and Cluster Production in Heavy Ion collisions

Author: Marcus Bleicher[None]

We present results on the production of light clusters in heavy ion collisions. We show that a coalescence approach yields a good description of the available data over the whole energy range. We extend our analysis to anti-deuterons (currently of interest due to the AMS measurement ni relation to dark matter) and strange hyper-clusters which are relevant for our understanding of the structure of neutron stars.

1

Open heavy flavor and quarkonium production in relativistic heavy ion collisions

Author: Jiaxing Zhao[1]

[1] *HFHF*

In relativistic heavy ion collisions, a deconfined QCD matter called quark-gluon plasma (QGP) is produced. Heavy quarks, due to their large masses, are mostly produced in the early stages of

heavy ion collisions and experience the whole evolution of the produced matter. So it can be a nice probe to the QGP. Meanwhile, the heavy quark energy loss, hadronization, quarkonium evolution and production in this ideal deconfinement environment provide opportunities to study the QCD properties under extreme conditions. In this talk, I will present several progresses our recently developed framework to describe both open heavy flavor and quarkonium.